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LINE MAPPING FROM SATELLITES IN THE ORDNANCE SURVEY

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Summary
This is an account of an actual production task using SPOT imagery. It also reviews the future of mapping from sensors in space and concludes that they have a role to play in future development and aid.

LINE MAPPING FROM SATELLITES IN THE ORDNANCE SURVEY

The current emphasis in the geographic and land information community on Geographic Information Systems (GIS) tends to take for granted the existence and accuracy of the topographic maps on which they are invariably based. In the UK we are fortunate in having some of the best medium scale mapping in the world at 1:50 000. In developing countries this may not be the case. While maps, at some scale, exist in most of the developing world, much of the cover is so out of date that it cannot be relied upon as a basis for identifying potential for new development. Some areas were mapped in the early years, by techniques that gave accuracy standards that are no longer acceptable for any purpose except basic navigation. As countries develop, or areas of potential are identified maps at scales larger than the existing 1:200 000 or 1:250 000 become necessary.

The basic techniques for topographic mapping have remained much the same for forty years. Stereo air photography is used as the basic source document, contours and topographic details being plotted photogrammetricly. Surveyed ground control is needed to orientate and scale the stereo models and field completion teams are needed to provide the essential information which is rarely apparent on any imagery; boundaries, road classifications, place names etc.

Over the years the costs of acquiring data and land information of all kinds and the heights of the sensors used to capture this data have risen progressively. One of the recent innovations in data capture has been the French SPOT-1 satellite which has been in a 'near Polar' circular orbit since February 1986. With its 10m pixel size, panchromatic image, off nadir viewing capacity, stereo capability and ability to accept commissions for imagery of specific areas, SPOT has characteristics which should be a boon to the cartographic community. The development of SPOT has generated a great deal of interest in the remote sensing and scientific community but despite many encouraging claims as to its utility and accuracy, so far very few cost effective products or processes have been developed.

Within the framework of an Overseas Development Administration funded topographic mapping program in the Yemen Arab Republic the Overseas Surveys Directorate of OS has experimented with the use of SPOT as a primary data source and has now started a production mapping programme. An area of 25 000 sq km in the north east of the country is being mapped at 1:100 000 scale with contours. Twenty eight SPOT scenes have been commissioned and a field survey team spent some months in this arid and unfriendly environment establishing the ground control necessary for mapping. It is a very good test bed for assessing satellite imagery; there is little vegetation to hide detail and there is virtually no cloud to prevent data capture. SPOT like all

visible band sensors cannot see through cloud, a vital but often underestimated limitation to most earth pointing remote sensors.

Mapping from SPOT is not simply a matter of tracing off detail from the imagery onto the map, the geometry of the image is both complex and dynamic. The SPOT HRV sensor has an array of 6000 Charged Couple Device sensors which sample reflected radiation every few micro seconds to create a digital image of a swath 10m long and 60km wide. Every swath has a perspective but off nadir view. A whole image is built up swath by swath while the satellite rotates around its Y axis to keep the sensor pointing at the earth. During the seven seconds it takes to record a 60km x 60km ground image the earth has revolved by up to 3.2km (at the equator) which means that an apparently square image represents a perspective view across a skewed area on the earth's surface. The complex geometry is compounded when using stereo imagery as the X axes of the two images taken of the same ground area from different orbits are converging (as the orbits of the satellites converge at the Poles). Discussion of the subject is further complicated as if the Z axis of the satellite is projected from the earth's centre through the satellite and a satellite's X axis is in the plane of the orbit the satellite's Y axis is nearly parallel to the X axis of the stereo image in the photogrammetric convention.

To make matters even more complex the satellite has perturbations ie it rocks about its axes and varies in its attitude, height and velocity. The end effect is such that a line which is straight on the ground appears as a wavy, skewed, far from straight, line on the image. Ground control points of known geodetic position which are positively identifiable on the image allow polynomial modelling of the image data to achieve photogrammetric restitution, in other words a scaled, orientated and usable model of the terrain. University College, London have developed the necessary algorithms and written these as software for use on an analytic photogrammetric plotter. Ordnance Survey quickly saw the benefit of such software and installed it on their own plotters.

The digital data, downloaded from SPOT, is not much use unless it can be seen, measured and interpreted. This is done by loading it into a digital image processing machine where the contrast can be manipulated to achieve a well toned and enhanced image. This is then plotted onto film using a laser plotting device where each original pixel, or data cell, is plotted at 30 micron size. The hardcopy image can then be loaded into the analytic plotter, surveyed control points and the satellite ephemerides data are entered into the system software and the processor calculates the photogrammetic solution. In effect, for any position selected in the model the computer first calculates the image coordinates then moves the left or right images to create a viewable model, then computes the ground co-ordinates and

finally moves the plotting head to the appropriate point on the new map plot. This complex calculation takes place fifty times a second which means that an operator can move his viewpoint around the image model in real time without any noticeable time lag.

Providing that sufficient ground control is available, that attitude variations in the satellite during the seven or so seconds required to expose the image are linear and the operator can distinguish ground features, the output map is effectively no different from any other small scale map.

There has, however, been a tendency for satellite data to be oversold in the past. A variety of tests undertaken in universities throughout the world have all indicated better than expected geometric accuracy and fidelity. Few workers like to advertise shortcomings but SPOT does have significant limitations. The 10m resolution makes positive identifications of features difficult or sometimes impossible. Data when you want and where you want it difficult to obtain, cloud, mist, dust or operational pressures on the satellite preclude early data acquisition and digital data is not necessarily any cheaper than air photography. The ambiguities in identification require more ground effort to confirm detail and to show the necessary classifications which help to make the topographic map usable. The greatest savings appear to be in plotting and computing times and, of course, the obtaining of data where local political pressure would preclude normal air photo sorties. Data acquired from space will not revolutionise mapping but will help it to evolve. OS regards this new data source as just that, another data form, with associated techniques and tools to help in producing an often underrated but vital value added product - a map.

The future for mapping from space seems to be assured. France is planning a continuous SPOT programme into the 21st century. The United States of America has recently announced plans for a 5m resolution scanner aboard the Landsat 6 satellite. Meanwhile the Soviet Union has recently made available, from their KFA-1000 camera, 1m resolution photographic data. The competition to supply high resolution data from satellites in low orbits appears to be increasing.

The British large scale map archive is not likely to be updated and revised by satellite data for a long time, if at all; a resolution of at least 1m will be required for that, but it is likely that, even with a complex urbanised landscape, maps at 1:25 000 scale and smaller may be revised from such data sources within the next decade.

The main market for such systems remains in the developing countries where basic topographic archives are so often out of date. It seems ironic that the technology transfer involved in

equipping local survey departments in the British Commonwealth over the last two decades can now be seen to leave us essentially as we were when we started. The developed world still has better data, techniques and expertise, the developing countries have the need.

Future developments in mapping systems are likely to revolve around a totally digital approach. Producing film from digital data (and vice versa) tends to degrade the image quality and interpretability so it makes good sense to keep the data in digital form. Image processing hardware and software is likely to be used more and more in traditional photogrammetry and map compilation. Already it is possible to produce digital terrain models from digital data fully automaticly: it can be but a few years before expert systems, artificial intelligence and computer vision systems, at present the subject of research, allow automatic feature recognition, extraction and labelling. In short, totally automated mapping.

This is a time of increasing commercial competitiveness in the mapping field and, indeed, in all types of aid input. With extreme economic pressures, and immediate human needs for food, shelter and disaster aid effecting many countries it is difficult to maintain a proper balance between the supply of such immediate necessities and the maintenance of the accurate geographic information which will underlie efficient and cost effective development in the future. Mapping, be it digital or conventional, old style paper sheets or new sounding geographic information, must take advantage of all opportunities to supply data more cheaply and more quickly. The use of satellite imagery needs further research and, more importantly, development before its true place in the cartographers' armoury is determined